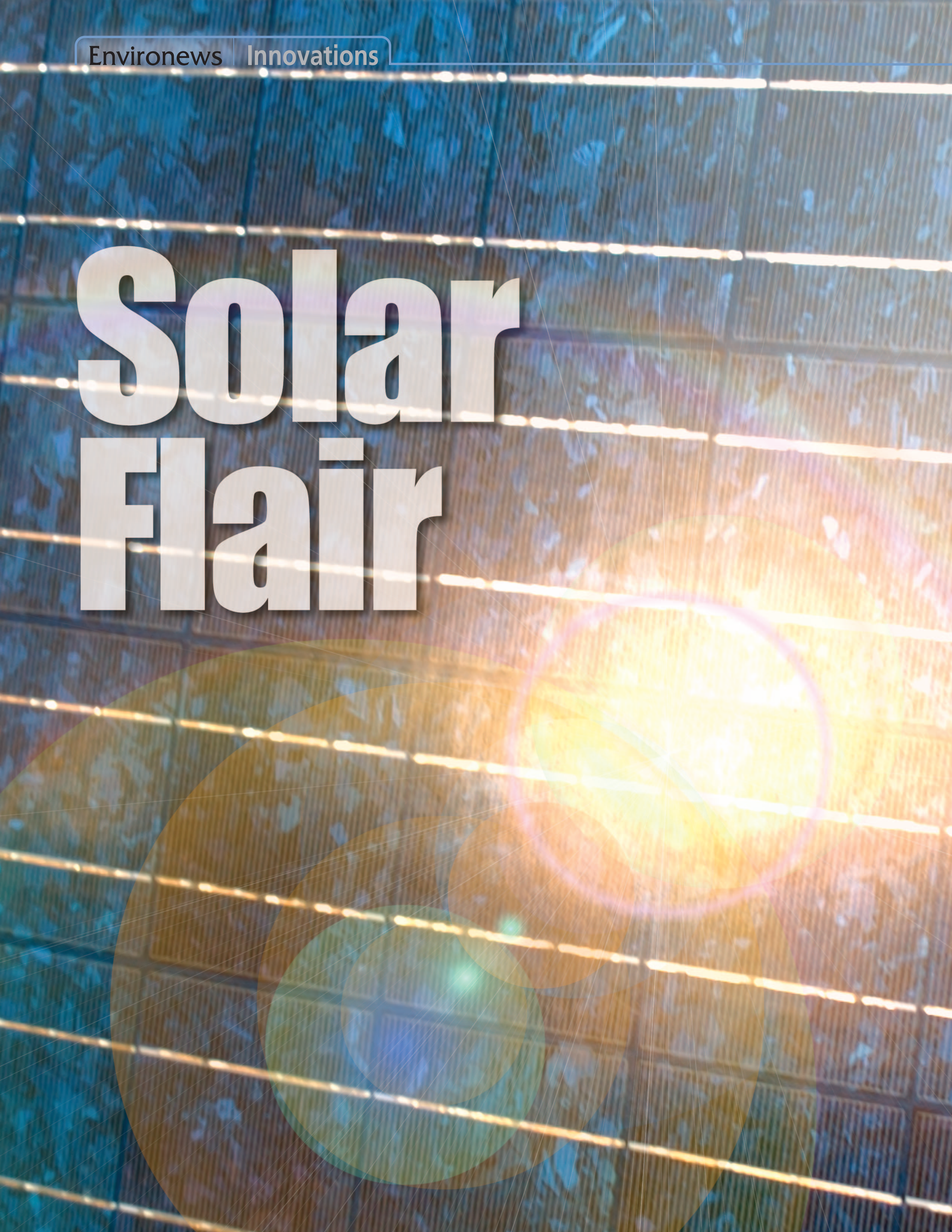
Solar Flair



Arnold Greenwell/EHP, Christopher G. Reuther/EHP

Public enthusiasm for solar design is like the winter sun in Seattle—it shines brightly for brief periods of time, then all but disappears. After a long period of dormancy marked by low energy prices and abundant supply, solar energy appears to be staging a comeback in the United States. High prices for electricity, combined with consumer rebates and other incentives, have the public in certain areas looking to the sun to supply a significant portion of their energy needs. And recent discoveries about the health benefits of solar technologies are bringing solar into some relatively new markets.

Although different styles have come and gone, the basic elements of solar design have changed little since their introduction during the oil crunches of the 1970s. Intelligent solar design starts with a well-insulated, tightly constructed building shell that contains the heat generated by the sun. Most of the window area is located on the south side of the building to let in maximum sunlight in winter. Window area is minimized on other sides to prevent unnecessary heat loss in winter and, in the case of western windows, to prevent overheating in summer. An extended roof overhang or operable form of shading is used on the south wall to block the high summer sun and prevent the house from overheating.

South-facing windows alone will help heat a building during the day, but to even out indoor temperatures and extend the functioning of the system into the night, it is necessary to add structural mass to the interior of the building. Masonry floors and walls can absorb sunlight during the day and release it as heat at night. Few people want their entire floor to be made of a hard, uncarpeted surface, but judicious placement of mass in south-facing rooms can add significant thermal comfort and energy savings.

South-facing glass, summer shading, and additional mass are the basics of “passive” solar design, a system that requires no mechanical devices to transform sunlight into useable heat. With advance planning, passive solar design can be incorporated into a new building at little or no extra cost. Yet for all its simplicity and common sense, only a small fraction of the homes built in the United States intentionally incorporate any passive solar design features.

“The great majority of homes are built through plan services that offer many choices in terms of style and size but relatively few solar features,” says Mike Nicklas, chairman of the American Solar Energy Society and president of Innovative Design, a North Carolina–based architectural firm. “Builders who want to use passive [solar] design either have to hunt for the few [existing] plans that may satisfy their customer or hire an architect, which they don’t do because of cost.”

A New Day Dawns for Daylighting

One element of passive solar design that is making some significant inroads into the institutional market is daylighting, the use of natural light to partially replace artificial lighting. As evidenced by the large and numerous windows in older factories and school buildings, daylighting was once commonly used in this country. However, large, multidirectional windows can be a source of unwanted energy gains and losses, and with the advent of fluorescent lighting and air-conditioning, designers greatly reduced window area in such buildings.

As electric costs have risen and studies have begun documenting the school and work performance advantages of sunlight, designers are returning to daylighting—with a twist. Rather than expose students or workers to direct sunlight through traditional placement of windows, designers are installing “roof monitors,” which have vertical glazing (rather than skylights’ usual horizontal panes) and employ internal baffles to deflect that light downward. Not only can daylighting cut energy bills by reducing the need for artificial light, it’s also yielding unforeseen benefit in terms of occupancy performance.

Innovative Design has pioneered the use of daylighting in school buildings in the Southeast. Shortly after building a host of new schools with daylighting features, Nicklas began hearing anecdotes from teachers and principals about improved student performance. “Teachers told us they were seeing remarkable improvements in test scores from kids working in daylit settings as opposed to artificial lighting," Nicklas says. "They say daylighting calms as well as stimulates the kids."

Teachers began noticing these effects in daylit schools in other parts of the country, too. In 1999, the San Francisco–based Pacific Gas and Electric Company commissioned a study by the Heschong Mahone Group, a California consulting firm specializing in building energy efficiency, to determine if other factors might be at work. Analyzing test scores for more than 21,000 students from school districts in California, Washington, and Colorado and using multivariate linear regression analysis to control for other variables, the Heschong Mahone Group found that the students with the most daylighting in their classrooms performed significantly better in both math and reading tests than those with the least amount of daylight. In an August 1999 report from Pacific Gas and Electric titled *Daylighting in Schools: An Investigation into the Relationship Between Daylighting and Human Performance*, the consultants wrote, "The three districts have different curricula and teaching styles, different school building designs, and very different climates. And yet the results of the studies show consistently positive and highly significant effects. This consistency persuasively argues that there is a valid and predictable effect of daylighting on student performance."

Power, Sunny Side Up

After space heating and daylighting, the next most common application of solar design is for domestic hot water. Solar water heaters usually consist of roof-mounted collectors connected to pipes and pumps that circulate water or a nonfreezing transfer fluid such as glycol to a conventional backup water heater in the home. Systems that use pumps or fans to transfer heat are referred to as "active" solar systems. Active solar water heating systems for residential use typically cost between $2,200 and $3,700. With a full 8 hours of sun exposure, they can save between $150 and $550 per year, depending upon the type and cost of the backup power used (for example, natural gas or electricity). According to Peter Lowenthal, director of the Washington, D.C.–based Solar Energy Research and Education Foundation, an estimated 6,000–7,000 systems are installed in the United States each year, 4,000–5,000 of those in Hawaii and the rest primarily in California, Florida, and Arizona.

Solar electric, or photovoltaic (PV), systems convert sunlight directly into electricity by means of wires embedded in either crystalline-silicon wafers or thin film modules. When sunlight strikes the cell, it generates a small amount of electricity in the form of direct current. This electricity can be used directly to power lights and other appliances specially designed to run on direct current, or it can be converted to alternating current, the type that comes from power stations and is used in homes and businesses.

During times of peak sunlight, PV systems may generate more electricity than the consumer needs. Batteries can be connected to the system to store excess electricity for use at night and on cloudy days. However, these batteries greatly increase costs and lower the power output due to system losses and limitations in battery voltage. Costs for residential PV systems without batteries vary widely depending on size, running anywhere from $10,000 to $30,000 prior to rebates and tax credits.

Residential systems are typically not powerful enough to run space heaters, air conditioners, or other major appliances. The high cost and relatively low power output of PV systems has traditionally limited their use to small applications in remote locales where it is costly or impossible to run an electrical grid. These applications include water pumping, remote communications systems, corrosion protection for pipelines and docks, and lighting for remote home sites, cabins, buoys, and billboards (for example, along interstate highways).

Although excess power can be stored in a battery system, if the home is connected to the electric grid, battery storage can be eliminated (thereby saving money) and the power sold back to the utility. Federal law requires utilities to buy electricity generated from customer-owned generating systems, but only at so-called avoided cost, which is a fraction of the retail cost. That is typically not enough to make PV systems economically attractive. However, in response to lobbying by solar power industries, a growing number of states are passing "net metering" laws, which require utilities to buy back power at the same rate they sell it to the customer. This, combined with consumer rebates and high utility rates, is making grid-connected PV systems economically attractive in some states—and is changing the solar power landscape.

Interest in PV systems is especially strong in California, a state that suffers from high electric rates and occasional power shortages. Starting in 2001, California began offering consumer rebates of $4,500 per kilowatt up to 50% of the system's purchase cost for PV and wind systems. The state also offers a 15% tax credit on the cost of systems after any rebates are subtracted, and has a net metering policy.

All of this has spawned a surge in PV installations in California—3,362 since 2001, with another 1,637 approved by the California Energy Commission but not yet installed. Most of these are residential systems in the 2- to 3-kilowatt range, but some are commercial systems of up to 500 kilowatts and more. Typical residential PV system costs run about $9–11 per watt of generating capacity (without battery backup) prior to rebates, according to Mike Iammarino, senior

Innovative Design

Reading, writing, and rays. Daylighting, which uses diffused sunlight as a replacement for artificial light, has been shown to boost student and worker productivity.

energy administrator with the utility company San Diego Gas and Electric.

A Collective Burst of Energy

Energy-efficient designs, active and passive solar design, daylighting, PV systems, and more were integrated in varying innovative ways into homes built for the 2002 Solar Decathlon. Sponsored by the U.S. Department of Energy (DOE), BP Solar, The Home Depot, Electronic Data Systems (an information technology services company based in Plano, Texas), and the American Institute of Architects (a professional group based in Washington, D.C.), the Solar Decathlon was so named because it included 10 competition categories. It was the DOE's first-ever international competition and included student teams from 14 colleges. Homes were erected on the National Mall in Washington and were open to the public 26 September–6 October 2002.

All of the homes had to generate their own power onsite using solar energy. PV panels had to be able to power an array of appliances, air-conditioning, a television set (on 6 hours a day), a satellite-linked computer, and an electric car battery pack good for 50 miles. The model homes were much smaller than typical American homes, but the technologies demonstrated could be applied to contemporary buildings.

"We had several goals for the decathlon, one of which was to bring architecture and engineering students together in the design process," says Cecile Warner, principal engineer for the National Renewable Energy Laboratory in Golden, Colorado, and project manager for the Solar Decathlon. "Traditionally, students from these disciplines have not held each other in high esteem, but in this competition, they had to work together and, as evidenced by the final products, they succeeded."

A second goal, Warner says, was to showcase renewable energy strategies for consumers. "This was also a success," she says, "as we had approximately one hundred thousand people go through the homes in three weeks."

First prize in the competition went to the University of Colorado. These students' chief goal was to prove that solar energy can work in virtually any house. They designed their house to look more like a traditional American home than an experimental solar house. The Colorado students developed what they call the Building a Sustainable Environment (or BASE+) approach, which starts out with a highly energy-efficient structure to which solar- and other energy-producing features

And sunlight for all. Entries in the first-ever Solar Decathlon (above), including the winning University of Colorado house (below), prove that any house can incorporate solar power.

U.S. DOE

can be applied. The modular-style house was built using structural insulated panels, which consist of a rigid foam center sheathed in oriented strand board or other materials. These panels eliminate the use of wood framing, which is a major source of heat loss. The Colorado house also included PV panels integrated into the roof, traditional passive solar features, and a solar hot water system.

Solar advocates have high praise for the Solar Decathlon and for the DOE's Million Solar Roofs Initiative, through which the federal government has committed to install solar systems on 20,000 federal buildings by 2010. (The million-roof goal extends beyond government efforts to the private sector.) Already, according to the DOE, the National Park Service has installed 700 PV systems on remote park buildings, ranging from single-module applications of about 35 kilowatts to the 115-kilowatt installation at Glen Canyon National Recreation Area.

Since the 2001 arrival of David Garman as DOE assistant secretary for energy efficiency and renewable energy, the budget for solar energy research and development has remained fairly steady at around $90 million, according to the DOE Office of Budget. That, combined with strong incentives in states including California, Illinois, and New Jersey, gives advocates hope that the sun will continue to shine on the solar energy movement.

"I'm encouraged by the overwhelmingly positive interest in solar [power], on the part of both major homebuilders and blue-chip companies, that we're seeing in states with well-designed incentive programs," says Glenn Hamer, executive director of the Solar Energy Industries Association. "It's important to remember that this is not just an economic benefit to the consumer—solar is also improving our health by reducing carbon dioxide and other pollutants generated by coal- and gas-fired generators. The trend is definitely in the right direction."

John S. Manuel

Suggested Reading

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